

WHAT IS CLAIMED IS:

5 1. A diffusion barrier layer for semiconductor devices the diffusion barrier layer having an upper surface and a lower surface and a central portion and comprising silicon, carbon, nitrogen and hydrogen, with the nitrogen being non-uniformly distributed throughout the diffusion barrier layer.

2. The diffusion barrier layer of Claim 1 wherein the nitrogen is more concentrated near the upper surface of the diffusion barrier layer compared to the central portion of the diffusion barrier layer.

10 3. The diffusion barrier layer of Claim 1 wherein the nitrogen is more concentrated near the lower surface of the diffusion barrier layer compared to the central portion of the diffusion barrier layer.

4. The diffusion barrier layer of Claim 1 wherein the nitrogen is more concentrated near the lower and upper surfaces of the diffusion barrier layer compared to the central portion of the diffusion barrier layer.

15 5. The diffusion barrier layer of Claim 1 further comprising oxygen.

6. The diffusion barrier layer of Claim 1 wherein a portion of the carbon and the silicon in the layer is in the form of silicon carbide.

20 7. A semiconductor device comprising
a substrate containing conductive elements; and,
a diffusion barrier layer applied to at least a portion of the substrate in contact with the conductive metal elements, the diffusion barrier layer having an upper surface and a lower surface and a central portion, and comprising silicon, carbon, nitrogen and hydrogen with the nitrogen being non-uniformly distributed throughout the diffusion barrier layer.

25 8. The semiconductor device of Claim 7 wherein the nitrogen is more concentrated near the upper surface of the diffusion barrier layer compared to the central portion of the diffusion barrier layer.

9. The semiconductor device of Claim 7 wherein the nitrogen is more concentrated near the lower surface of the diffusion barrier layer compared to the central portion of the diffusion barrier layer.

10. The semiconductor substrate of Claim 7 wherein the nitrogen is more concentrated near the lower and upper surfaces of the diffusion barrier layer as compared to the central portion of the diffusion barrier layer.

11. The semiconductor device of Claim 7 wherein the nitrogen is distributed only in the upper surface of the diffusion barrier layer.

12. The semiconductor device of Claim 7 wherein the conductive elements are made from a metal selected from the group consisting of Ti, TiN, TiW, Ta, TaN, W, Al, Pd, Cu and combinations thereof.

13. The semiconductor device of Claim 7 wherein the conductive elements are made from Cu.

14. The semiconductor device of Claim 7 wherein the thickness of the diffusion barrier layer is from about 7 nm to about 120 nm.

15. The semiconductor device of Claim 7 wherein the thickness of the diffusion barrier layer is from about 24 nm to about 68 nm.

16. The semiconductor device of Claim 7 wherein a portion of the carbon and the silicon in the layer is in the form of silicon carbide.

17. A method for making a semiconductor device which comprises the steps of:
a) providing a substrate containing conductive elements; and
b) forming a diffusion barrier layer on at least a portion of the substrate in contact with the conductive metal elements, the diffusion barrier layer having an upper surface and a lower surface and a central portion, and comprising silicon, carbon, nitrogen and hydrogen with the nitrogen being non-uniformly distributed throughout the diffusion barrier layer.

18. The method of Claim 17 wherein the step of forming a diffusion barrier layer results in the nitrogen being more concentrated near the upper surface of the diffusion barrier layer compared to the central portion of the diffusion barrier layer.

19. The method of Claim 17 wherein the step of forming a diffusion barrier layer results in nitrogen being more concentrated near the lower surface of the diffusion barrier layer compared to the central portion of the diffusion barrier layer.

20. The method of Claim 17 wherein step of forming a diffusion barrier layer results in the nitrogen being more concentrated near the lower and upper surfaces of the diffusion barrier layer as compared to the central portion of the diffusion barrier layer.

21. The method of Claim 17 wherein the step of forming a diffusion barrier layer results in diffusion barrier layer further comprising oxygen.

22. The method of Claim 17 wherein the substrate provided in step (a) contains conductive elements formed from a metal selected from the group consisting of Ti, TiN, TiW, Ta, TaN, W, Al, Pd, Cu and combinations thereof.

23. The method of Claim 17 wherein the conductive elements are formed from Cu.

24. The method of Claim 17 wherein the step of forming a diffusion barrier layer produces a diffusion barrier layer having a thickness from about 7 nm to about 120 nm.

25. The method of Claim 17 wherein the step of forming a diffusion barrier layer produces a diffusion barrier layer having a thickness from about 24 nm to about 68 nm.

26. The method of Claim 17 wherein the step of forming the diffusion barrier layer comprises atomic layer deposition.

27. The method of Claim 17 wherein a portion of the carbon and the silicon in the layer is in the form of silicon carbide.

28. A method comprising: forming a diffusion barrier layer on a conductive material, the diffusion barrier layer having an upper surface and a lower surface and a central portion and comprising silicon, carbon, nitrogen and hydrogen with the nitrogen being non-uniformly distributed throughout the diffusion barrier layer, whereby adhesion between the conductive material and the diffusion barrier layer is improved compared to the adhesion between the same conductive material and a diffusion barrier layer having a uniform nitrogen distribution.

29. The method of Claim 28 wherein the nitrogen is more concentrated near the upper surface of the diffusion barrier layer compared to the central portion.

30. The method of Claim 28 wherein the nitrogen is more concentrate near the lower surface of the diffusion barrier layer compound to the central portion.

31. The method of Claim 28 wherein the nitrogen is more concentrated near the lower and upper surfaces of the diffusion barrier layer as compared to the central portion of the

diffusion barrier layer.

32. The method of Claim 28 wherein the diffusion barrier layer further comprises oxygen.

33. The method of Claim 28 wherein the conductive material is selected from the group consisting of Ti, TiN, TiW, Ta, TaN, W, Al, Pd, Cu and combinations thereof.

34. The method of Claim 28 wherein the conductive metal material is Cu.

5